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THE ACCOMMODATIVE STATUS IN THE DARK OF U. S. NAVY FIGHTER PILOTS

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March 1987

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PENSACOLA, FLORIDA

Volunteer subjects were recruited, evaluated, and employed in accordance with the procedures specified in Department of Defense Directive 3216.2 and Secretary of the Navy Instruction 3900.39 series. These instructions are based upon voluntary informed consent and meet or exceed the provisions of prevailing national and international guidelines.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

A188188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S): NAMRL - 1332

5. MONITORING ORGANIZATION REPORT NUMBER(S):

6a. NAME OF PERFORMING ORGANIZATION: Naval Aerospace Medical Research Laboratory

6b. OFFICE SYMBOL *(If applicable)*: 23

7a. NAME OF MONITORING ORGANIZATION: Naval Medical Research & Development C[illegible]d

6c. ADDRESS *(City, State, and ZIP Code)*: Naval Air Station, Pensacola, FL 32508-5700

7b. ADDRESS *(City, State, and ZIP Code)*: Naval Medical Command, National Capital Region, Bethesda, MD 20814-5044

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: Naval Medical Research and Development Command

8b. OFFICE SYMBOL *(If applicable)*: Code 404

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS *(City, State, and ZIP Code)*: Commanding Officer, Naval Medical Research and Development Command, Naval Medical Command, National Capital Region, Bethesda, MD 20814-5044

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
63706N	M0096	M0096.01	1053

11. TITLE *(Include Security Classification)*: (U) The Accommodative Status in the Dark of U. S. Navy Fighter Pilots

12. PERSONAL AUTHOR(S): Leonard A. Temme and E. L. Ricks

13a. TYPE OF REPORT: Interim

13b. TIME COVERED: FROM ______ TO ______

14. DATE OF REPORT *(Year, Month, Day)*: 8703

15. PAGE COUNT: 28

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*: Accommodation, dark focus, night vision, naval aviation

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Visual accommodation of 172 naval aviators in the dark was measured and compared to their most recent night carrier landing scores and the average distance at which an adversary aircraft was first sighted during air combat maneuver training. No significant correlations were found between the accommodation measures and either measure of operational performance. Reasons for this result are discussed.

Accommodation measures made in the aviator sample in the dark are compared to measures made in samples of college students reported in the literature. The aviator sample is significantly less myopic than the student sample. For example, only 6% of the students have as little myopia as the average naval aviator. This dramatic difference in accommodation could result from either training or some set of selection factors. Possible reasons for this finding and its significance for the Navy are discussed.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: J. O. HOUGHTON, CAPT MC USN, Commanding Officer

22b. TELEPHONE *(Include Area Code)*: (904) 452-3286

22c. OFFICE SYMBOL: 00

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

U.S. Government Printing Office: 1985—507-047

UNCLASSIFIED

SUMMARY PAGE

THE PROBLEM

In a dark or in an empty lighted visual field, the eye tends to be myopic even though it may be emmetropic in a normally lighted and detailed environment. This tendency toward myopia may significantly affect the ability of an aviator to fly at night or in a sky field void of visually contrasting stimuli. The purpose of the present research was to find out: (1) whether accommodation of Navy fighter pilots in the dark is different from that of non-aviators, and (2) whether the accommodative state of aviators is correlated to their performance of night carrier landings or to air-to-air target detection.

FINDINGS

The accommodative state in the dark of the sample of Navy aviators was significantly and dramatically different from that reported for samples of non-aviators. For example, 50% of the aviators had less myopia in the dark than 94% of a reported sample of 220 college students; less than 10% of the aviators had as much myopia as 50% of the college students.

The operational performance of the naval aviators did not correlate significantly with their accommodative state measured in the dark in the laboratory. The absence of a significant correlation may be due to the small amount of myopia in the sample of aviators tested and the restricted range of operational performance scores.

RECOMMENDATIONS

The origin of the observed differences between the fighter pilots and non-aviators should be explored. Non-aviators should be tested with the same apparatus and in the same fashion as the aviators were tested, to eliminate any possibility that the differences observed between the samples were due to methodological and procedural differences. If the differences are not methodological or procedural in origin, then control of accommodation in the dark may be a selection factor for Navy aviators or, alternatively, control of accommodation in the dark may be influenced by aviation training. Steps could be taken to optimize these factors for either selection or training.

Lastly, we recommend exploring the possibility that the accommodative state in the dark may provide a useful indication of the rate of the development of refractive error with aging, or the effects of extended near work upon far vision.

ACKNOWLEDGMENTS

We thank Dr. Ailene Morris and Dr. Paul Hamilton for their help in all aspects of this work; Dr. James D. Grissett for his encouragement; Dr. Thomas Amerson for his very helpful discussions and suggestions; Mrs. Julie Gandy for secretarial support, Mrs. Nell Davis for technical support, and Mr. Chuck Mogensen for making the figures.

INTRODUCTION

The accommodative apparatus of the eye functions to focus an image of an object onto the retina (1). With the stimulus conditions arranged to place little or no demand on the accommodative apparatus, it goes to a resting state (11). The nature of this resting state of accommodation is at issue. The classical theory describes it as a state in which the ciliary muscle is maximally relaxed, which in turn causes a maximal flattening of the lens (1,30). A maximal flattening of the lens causes the eye to be focused at its far point. Although classical theory predicts that the eye at rest would be focused at its far point, recent literature indicates that the eye focuses closer than far point in conditions in which the eye should be relaxed (22,23). These conditions produce the anomalous myopias, the most commonly discussed of which are night myopia, empty field myopia, and instrument myopia (7,14,15,29,32). Night myopia refers to the observation that the eye tends to focus closer in the dark than in the light. Empty field myopia refers to the observation that in a lighted unstructured field, the eye tends to focus closer than in a lighted and structured field. Instrument myopia refers to the observation that a individual tends to focus optical instruments, such as microscopes and telescopes, as if to compensate for a myopic condition. Evaluating the significance of these anomalous myopias for the classical theory is difficult because different investigators and procedures measure different amounts of myopia (22,30,32). Furthermore, post hoc explanations, which have been proposed to reconcile the classical theory with the observed myopias, attribute these myopias to a variety of contributing factors (12,18).

Leibowitz and his associates have helped to clarify the situation. From their work an alternative hypothesis emerged, which conceptualizes the resting state of accommodation as an intermediate point, which is less than the far point (10,14,15,16). A stimulus for accommodation is one that pulls it from its resting state. Accommodation to a stimulus is a compromise between the necessary effort of the accommodative apparatus to generate a retinal image of adequate optical quality and the tendency of the apparatus to remain at a resting or tonic posture. Three important ideas are identified in this theory: (1) the ability of the stimulus to drive accommodation, (2) the tendency of accommodation to be at its resting state, and (3) the "adequacy" of a retinal image.

Leibowitz and his associates have developed the first two ideas most thoroughly. They found that as illumination or contrast of a stimulus decreases, a consistent tendency to over accommodate the distant stimulus and under accommodate the near stimulus occurs (10). Accommodation is most accurate with the stimulus at the distance of the subject's accommodation at rest. The ability of a grating stimulus to drive accommodation is predicted by the contrast sensitivity to the grating (21). Furthermore, as the quality of the stimulus decreases, so does its ability to pull accommodation from its intermediate resting position (22,23). This conceptualization may yet provide a framework for a metric with which to evaluate the visual effectiveness of supra-threshold stimuli encountered in the real world; i.e., by the relative accuracy of the accommodative response.

The third idea is that an individual accommodates to a stimulus for a specific purpose, and accommodation produces an image of adequate quality

for that purpose but not necessarily better than needed. The resolution necessary to identify a roundish object as a face is less than that necessary to identify the specific face; therefore, the context of a visual task most likely is a factor influencing the accuracy of accommodation (30).

Accommodation in the dark has been reported in college students. The data of Leibowitz and Owens (16), in Figure 1, are characteristic in that an average dark myopia of between 1 and 2 diopters (D) with a standard deviation of about 1 D are most commonly reported. A survey of the accommodative state in the dark of 154 U. S. Air Force recruits has reported a mean myopia of 1.2 D with a standard deviation 1.5 D (30). The same study reported a survey of 114 college students with an average of 2.7 D of myopia and a standard deviation of 2.6 D. The difference between the students and Air Force recruits is statistically significant. It was suggested in the report that this difference between the two groups may be due to a process of self selection; that is, individuals who otherwise would have applied to the Air Force did not because they perceived themselves to be too myopic to qualify (30).

The significance to aviation of the accommodative state in a dark or an empty visual field has been previously recognized and often discussed (8,13,26,27,28). Aviators routinely fly at night and in sky fields with few if any visual stimuli of appreciable contrast--situations conducive to night and empty field myopia. We have drawn two hypotheses from this fact. First, the accommodative state in the dark measured in the laboratory may provide an indication of the posture accommodation tends to assume in the cockpit at night and in an empty sky field. If this is true, then night carrier landing scores and air-to-air target detection may be expected to correlate with accommodation in the dark in the laboratory. Second, the accommodative state of aviators in the dark as a group may be significantly less myopic than that of other, less selected samples.

To evaluate these hypotheses, we measured the accommodative state of 172 U. S. Navy fighter pilots in the dark in a laboratory setting. The measurements were made between June 1983 and October 1985 in the NAMRL Mobile Field Laboratory (MFL) at NAS Oceana, Virginia Beach, VA. The measurements were made during the time the aviators were participating in Air Combat Maneuver (ACM) training at the Tactical Air Combat Training System (TACTS) range. The distance at which an aviator first reported visually sighting an adversary aircraft during ACM training, slant range, was one measure of flying performance compared with that aviator's accommodation in the dark. We used this task because it is the detection of a small visual stimulus in a sky field that may have few contrasting contours. Since myopia is known to reduce sensitivity to a spot of light (20), we hypothesized that aviators who are subject to empty field myopia would detect adversary aircraft at closer distances than aviators who are not subject to empty field myopia. The amount of myopia evident in an empty field is highly correlated with the amount of myopia evident in the dark (14). In addition, a second measure of flying performance, the most recent night carrier landing scores of the participating aviators, was obtained for comparison with accommodation in the dark. We hypothesized that aviators who are more myopic in the dark would have poorer night carrier landing scores than aviators who are less myopic in the dark.

METHODS

APPARATUS

Measurements were made with a laser-Badal optometer, which is described in the literature (2,5,6,9) and shown in Figure 2. The light source was a 1.0-mW helium neon laser (632.8 nm) with its beam diverged, passed through a shutter, and reflected from a front-surface mirror onto an anodized aluminum drum rotating at 1.0 rpm. The drum surface reflected the beam through an iris, a +5.0-D Badal lens, and onto a half-silvered mirror that reflected the beam into the observer's eye. The eye was positioned at the focal plane of the Badal lens. A head and chin rest was used to stabilize eye position. The drum, front-surface mirror, shutter, and laser were mounted on a carriage, which was moved along a unislide toward or away from the Badal lens. A linear potentiometer was attached to the carriage, and a timing belt was attached to the unislide frame so that movement of the carriage turned the potentiometer. A digital voltmeter displayed the voltage output of the potentiometer. The voltage was calibrated to be directly proportional to the carriage position.

PROCEDURE

When the shutter was opened, the beam of the laser was reflected off the surface of the drum to the half-silvered mirror through which the observer was looking. The interference pattern produced by the scatter of the coherent light from the drum surface was apparent to the observer as a granular or speckle pattern. With the movement of the drum surface, one of three percepts is typically reported: (a) with the retina of the observer conjugate to a plane in front of the plane of scatter drum rotation produces a speckle pattern that appears to move in the direction opposite drum rotation; (b) with the retina of the observer conjugate to a plane behind the plane of scatter, drum rotation produces a speckle pattern that appears to move in the same direction as drum rotation; (c) with the retina conjugate to the plane of scatter, the motion is nondirectional and appears as a bubbling or scintillating stationary image (2).

The experimental approach was to position the drum-laser assembly at various locations along the unislide; open the shutter for 400 ms; and from the subject's responses, identify the plane that produced a stable, bubbling percept, that is, the plane of stationarity. From this, we calculated the refractive power of the eye in the dark (2). The stimulus duration was set at 400 ms because the accommodative apparatus takes about this long to initiate a response to a stimulus. The speckle-pattern stimulus, therefore, was presented and terminated before a change in accommodation could be effected (1,31).

The room was illuminated throughout the period of instructions, alignment of the subject, and familiarization with the equipment. The subject was positioned with his head stabilized. The apparatus was adjusted so that the speckle pattern was moving, and the following instructions were given: "Do you see a round, red, colored target? If it is not round, raise or lower your stool slightly or move the chin rest until the target is round. Notice the surface of the target. Do you see small pebble-like objects on the surface? Do they appear to be moving? What direction? Now

watch the pebbles. (At this time the experimenter reversed the direction of rotation of the drum). What happened to the pebble surface of the target? (The correct answer was that it reversed the direction of flow. Then the experimenter stopped the drum rotation). Now what are the pebbles doing? Are they moving? (The correct answer was that there was no motion). During the test, which will be done in total darkness, you will remain in the headrest. I will instruct you to standby. The target will appear for 400 ms, after which you will answer 'up, down, or no' depending upon pebble movement. No movement denotes a threshold, and that is what we are testing for. At times it may be difficult to determine the movement of the pebbles. This should be considered a 'no' answer. The lights will be turned off for 2 min for you to dark adapt."

At the end of 2 min, the subject was asked to get back in position in the headrest. The shutter was opened for 400 ms, and the subject was asked if a full round target was visible. The subject was also instructed to indicate anytime during the test if the target did not appear round.

The drum-laser-mirror assembly was moved to one end of its travel, the direction of drum rotation was set, the subject was alerted, and the stimulus was presented. The subject's verbal report of the apparent motion was recorded. The drum assembly was then moved about 20 cm toward the middle range, and the next stimulus was presented. This process was repeated until the subject reported that the apparent direction of the speckle pattern reversed. The sequence of stimulus presentations necessary to produce a reversal of apparent motion constituted one run; thus, each run contained responses on either side of the plane of stationarity and required at least three target exposures.

Six runs were recorded for each subject. For runs 2 to 6, the distance that produced a response of "no motion" was converted to diopters and analyzed. The first run was considered practice, and it was not included in the analysis.

SUBJECTS

We tested 172 U. S. Navy fighter pilots attached to Fighter Wing One, who participated in ACM training at NAS Oceana, Virginia Beach, VA, between June 1983 and October 1985. All the subjects were male, ranging in age from 24 to 44 years, with a mean age of 30 years (<u>SD</u> = 4.1).

RESULTS

Data from a representative, single test session for a single aviator are shown in Figure 3. The abscissa is the distance in meters between the Badal lens and the drum. There is a linear relationship between this distance and accommodation in diopters. For run 1, the speckle pattern appeared to flow upward with the drum at .1043 and .1457 m; it appeared to be stationary with the drum at .1706 m; and it appeared to flow downward with the drum at .1808 m. For run 2, the direction of drum rotation was reversed as indicated. The speckle pattern appeared to flow downward with the drum at .1436 m; it appeared stationary with the drum at .1567 m; and it appeared to flow upward with the drum at .1908 m. The arrows indicate the distances we used to calculate the accommodative state. The mean and

standard deviation in diopters of the five runs (2 to 6) were calculated. Data in Figure 3 are representative of those from 98 of the aviators, in that an unambiguous reversal in the direction of apparent speckle-pattern flow as a function of drum distance was apparent for at least five of the runs.

Figure 4 contains data from another aviator in which one run, run 4, was ambiguous in that the "Down" response occurred between the "No" and the "Up" responses. For this aviator, the mean diopter value was calculated from runs 2, 3, 5, and 6. There were 39 aviators whose data was ambiguous in one or two runs; the mean diopter value was based on three or four runs.

In Figure 5 are data that demonstrate clearly that the myopia of one aviator in the dark exceeded the range of the optometer. This conclusion is evident from the consistent relationship between the direction of drum rotation and the apparent direction of speckle flow. With the exception of run 2, the speckle pattern always appeared to flow in the direction of the drum rotation, regardless of drum distance. This aviator, therefore, evidenced more than 3.0 D of myopia, the limit of measurement of the optometer. This occurred in a total of six aviators, and their data were excluded from the group statistics because a mean value could not be determined.

The records of 15 other aviators indicated that they could not see the moving speckle pattern when it was flashed for 400 ms; with a longer flash duration, about a second or so, however, these subjects reported that the speckle pattern was visible. Data from these subjects were excluded from the group statistics, as were the data of another 14 aviators for which the records either indicated equipment failure or were incomplete. The above categorization of the 172 aviators is summarized in Table 1.

TABLE 1. Summary Optometer Measurements of 172 Aviators.

Category	Frequency	Mean (D)	*SD* (D)
Reliable responses on 5 runs	98	.25	.84
Reliable responses on 3 or 4 runs	39	.82	.86
Myopia exceeds operational range of the optometer	6	-	-
Unsystematic or unreliable responses on the majority of runs	15	-	-
Equipment failure or incomplete data	14	-	-

In Figure 6 are histograms of the average accommodative state in the dark of the 137 (98 + 39) aviators from whom responses were obtained in 3, 4, or 5 runs. These histograms were transformed into the percentage cumulative frequency distributions shown in Figure 7. The 98 aviators who responded on five runs had a mean of about 0.25 D myopia and a standard deviation of 0.84 D. The 39 aviators responding in three or four runs had a mean of about 0.82 D of myopia with a standard deviation of 0.86 D. The difference between these two groups of aviators is significant ($t = 3.51$, $p < 0.0008$). In other words, the aviators for whom one or two of the runs were ambiguous were significantly more myopic in the dark than the aviators who responded unambiguously on the five runs.

In Figure 7 are also shown the percentage cumulative frequency distribution for the sample of 220 students reported by Leibowitz and Owens (16) shown earlier in Figure 1. Those students had a mean in the dark of 1.5 D of myopia and a standard deviation of 0.77 D, which is significantly more myopic than our sample of 39 aviators having a mean of 0.82 D of myopia ($t = 4.89$, $p < 0.001$). In Figure 8, we compared data from our combined sample of 137 aviators to that of the 220 college students. The aviators had a mean of 0.41 D and a standard deviation of 0.88 D, which is significantly different from the college students ($t = 12.25$, $p < .001$).

TABLE 2. Pearson Coefficients of Correlation Between the Accommodative State in the Dark and Operational Performance Scores of Night Carrier Landings (NCLS) and Slant Range.

Aviators (n)	Accommodation	NCLS	Slant range
98	Mean	$r = .056$ ($p = 0.62$)	.059 (0.59)
	SD	-.196 (0.08)	0.27 (0.80)
	Range	-.145 (0.197)	0.35 (0.75)
39	Mean	.105 (0.63)	-.141 (0.42)
	Range	.115 (0.59)	-.295 (.09)
137	Mean	.021 (0.83)	-.073 (0.43)
	Range	-.090 (0.35)	-.069 (0.45)

The Pearson coefficients of correlation between accommodation in the dark and the operational performance scores are shown in Table 2. These correlations were calculated separately for the sample of 98 aviators with five trials, for the sample of 39 aviators with 3 or 4 trials, and for these two samples combined. The operational performance scores were correlated with the mean and range for the three aviator samples. In addition, for the sample of 98 aviators from which five trials were available, the standard deviation of the measurements of accommodation was correlated with the operational performance scores. None of the correlations was statistically significant. The correlations between mean accommodation and NCLS or slant range have significant probabilities of between 0.43 to 0.83.

DISCUSSION

Consistent and reliable data were obtained on all 5 runs from 98 of the 172 aviators and on 3 or 4 runs from another 39 aviators. In six aviators, the amount of myopia in the dark was at or exceeded the range of the optometer and was therefore at least 3.0 D. The pattern of response for 15 aviators indicated that these aviators were not able to see or respond in a consistent fashion to the stimulus. Equipment failure or incomplete records prevented an adequate determination of the accommodative state in 14 aviators.

AVIATORS AND NON-AVIATORS

One of our objectives was to determine whether or not accommodation in the dark differs between Navy fighter pilots and non-aviators. We found the student and the aviator data were significantly and dramatically different. For example, more than 30% of the aviators evidenced no myopia in the dark and were even hyperopic; a characteristic of less than 5% of the students. Also, 50% of aviators had as little as 0.3 D of myopia in the dark, whereas less than 6% of the students had such a small amount of myopia. About 50% of the students had 1.4 D or more of myopia in the dark; less than 10% of the aviators had this much myopia.

The mean of 0.41 D of myopia in the dark of the 137 aviators is probably an underestimation, since the optometer used to collect the data from the aviators could not measure myopia greater than about 3.0 D. The response pattern of six aviators indicated a dark myopia greater than this; but despite this underestimation, it is unlikely that the mean values of the student and aviator samples are comparable. If as much as 8 D of myopia is attributed to these six aviators, then the average amount of myopia of the whole aviator sample would be increased to 0.73 D, which is still 1.0 SD less than the college student average. Myopia of this magnitude in these six aviators is extremely unlikely.

Despite the fact that the average of 0.41 D is likely to be a slight underestimation, the naval aviator has remarkably little myopia in the dark. The origins of the differences between the student and aviator samples remain to be determined. The question is: Do individuals with less myopia in the dark become fighter pilots, or do individuals during the course of fighter pilot training become less myopic in the dark?

The students and the naval aviators were measured with optometers of the same design and with the same general experimental approach. That is, each subject was presented with a laser speckle pattern flashed for about 400 ms. Despite the superficial similiarity in apparatus and experimental approach, the studies differed on many levels. Different experimenters, apparatus, environment, motivation levels, et cetera, were involved, and accommodation is known to be affected by a large number of such factors (17,19,26). In view of this, any comparison between the students and aviators should be considered suggestive rather than definitive. Ideally, fighter pilots, other aviators, and non-aviators should all be tested on the same apparatus in the same environment by the same experimenter to make any definitive comparisons.

Concistent and reliable data were obtained on all 5 runs from 98 aviators and on 3 or 4 runs from 39 aviators. The sample of 98 aviators was significantly less myopic than the sample of 39 aviators ($t = 3.51$, $p < 0.0008$). This difference shows that individuals who can respond unambiguously on all five trials are, on the average, 0.57 D less myopic then individuals whose responses are ambiguous on one or two runs. This difference in response ambiguity was not apparent in response variability; the average range of responses for individuals from either group was essentially the same (0.62 and 0.64 D). Furthermore, the standard deviation of both groups was essentially the same (0.82 and 0.84 D). Thus, the cause for the ambiguous response on the one or two runs did not increase response variability on the other trials. Presently, we cannot see how the greater myopia of the one group could account for the greater number of ambiguous runs.

OPERATIONAL PERFORMANCE AND ACCOMMODATION IN THE DARK

A major aim of the present research was to relate measurements of visual processes to aviation performance in the field. We hypothesized that night carrier landing and air-to-air target detection would be related to the accommodation state measured in the dark in the laboratory. Night carrier landings require complex precise visual discriminations in a dark field--a situation conducive to night myopia. Air-to-air target detection requires visual detection in a field often void of contrasting stimuli of high spatial frequency--a situation conducive to empty field myopia.

Empty field and night myopia are highly correlated (14). To evaluate these hypothesized relationships between field performance and laboratory measurements, the most recent NCLS were obtained for the aviators. In addition, the performance of these aviators on the TACTS range was monitored, and the average distance of the adversary aircraft at first sighting was recorded for each aviator. This distance, slant range, is a measure of air-to-air target detection performance.

Pearson coefficients of correlation between accommodation and operational performance measures are summarized in Table 2. None of these correlations was significant; thus, the hypothesized relationship between aviation performance and accommodation in the dark was not demonstrated. This relationship would have been substantiated if performance decreased with increased myopia in the dark.

About half the aviators had an insignificant amount of myopia in the dark; many of the aviators were hyperopic. The absence of a correlation may be due to the fact that a large percentage of the aviators did accommodate adequately in the dark.

The relationships between operational performance and the measures of the variability of accommodation, the range and standard deviation, merit a closer look. The correlation between standard deviation and slant range was not statistically significant ($r = 0.27$, $\underline{p} = 0.80$); the correlation between the standard deviation and NCLS was suggestive ($r = -0.196$, $\underline{p} = 0.08$). The relationship is inverse; aviators with greater standard deviations have poorer night carrier landing scores. This relationship may indicate that the variability of accommodation around its mean is more significant for an individual's night carrier landing performance than the mean itself. This correlation was based upon the sample of 98 rather than the 137 aviators because accommodation for 39 of the 137 aviators was based on fewer trials. The ranges of accommodation scores were calculated for the 137 aviators to assess the relationship between accommodative variability and NCLS with a large number of aviators. The correlation between range and NCLS was low and not suggestive of a relationship, as was the standard deviation.

To explore further the possible relationship between operational performance and accommodation in the dark, the total of 172 aviators was divided into 2 groups on the basis of their optometer measurements. In one group were the aviators whose accommodation was measured in the dark and shown to be less than two standard deviations from the group mean; that is, all the aviators who had less than 2.17 D of myopia in the dark. In the other group were the aviators whose myopia exceeded the mean by 2.0 SD. This group consisted of the six aviators whose myopia in the dark exceeded the range of the optometer as well as the three aviators whose myopia was measured to be greater than 2.17 D. In addition, this group also included the 15 aviators whose data were inconsistent and ambiguous on the majority of the trials. Thus, there were 134 aviators in 1 group and 24 in the other. The NCLS of these two groups, as well as their slant ranges, were compared using t tests. No differences were found between these two groups for either measure of operational performance. A relationship between accommodation measured in the dark and either night carrier landing performance or slant range was not supported by these data.

IMPLICATIONS AND SIGNIFICANCE

The absence of a correlation between accommodation in the dark and the operational performance scores may at first be puzzling, but two aspects bear consideration. First, these are all excellent aviators, and the range of operational performance may not be sufficiently large to reflect the influence of accommodative state. The aviators who tend to be most myopic in the dark may even have compensating excellence in some other dimension, (e.g., situational awareness, spatial localization, eye-hand coordination, or experience). That is, those who perform most poorly on one laboratory test may also be the ones likely to excel on some other laboratory test. Any aviation task is a complex sensory-motor task to which skills and aptitudes in a large number of sensory domains contribute.

The second aspect to consider is that the aviator and the college student apparently differ statistically and dramatically in accommodative status. If further research substantiates this, then, paradoxically, a correlational analysis of accommodation in the laboratory and operational performance may never reach levels of significance. Individuals whose accommodation in the dark is below a certain level may never become adequate aviators and may never become part of the tested aviator sample. Thus, although accommodative state in the dark may be an essential factor, a correlational analysis would fail to demonstrate it. If the sample of aviators and the sample of college students truly do differ in accommodative state in the dark, as our data strongly indicate, it may well be because this visual characteristic is very important for success in military aviation. The identification of the sources of the difference between these two samples now seems to be of great practical importance. If the difference is a factor for personnel selection, it should be incorporated in the physical qualifying exam. If the difference is due to training, then special consideration should be given to training accommodation. If the difference is due only to procedural or methodological factors, this should also be established.

Some evidence exists that the state of accommodation in the dark may be a useful indicator of the tendency of a individual to develop myopia, particularly in relationship to the demands of near vision work. For example, individuals with a far accommodative state in the dark may be affected more adversely by extended near work than individuals with a nearer accommodative state in the dark (3,4,25). Ocular posture in the dark or at rest may then possibly provide information about the progression of refractive errors and also provide a basis for prescribing preventive action. For example, individuals with a far accommodative state in the dark may benefit from glasses prescribed for near work that would optically bring closer the accommodative state in the dark. In this vein, the impact of the state of vergence in the dark should also be considered (24). Accommodation and vergence measured in the dark may be important for naval aviation as a way to predict and ameliorate the progression of refractive errors, as well as provide a basis for personnel selection.

CONCLUSIONS

The accommodative state in the dark of the sample of naval aviators was significantly and dramatically different from that reported for non-aviators. For example, 50% of the naval aviators had as little myopia in the dark as about 6% of a reported sample of 220 college students; conversely, less than 10% of the aviators had as much myopia as 50% of the college students. The operational performance of the naval aviators as measured by slant range and NCLS scores did not correlate significantly with their accommodative state in the dark in the laboratory.

The origin of the observed differences between the aviators and non-aviators should be explored. It is possible that they could be attributable to methodological and procedural differences since the non-aviator sample was obtained from published data collected in a different laboratory

although with comparable procedures and apparatus. Aviators and non-aviators should be tested with the same apparatus and in the same fashion to eliminate any possibility that the differences observed between the samples were due to methodologies.

The potential significance of these findings is very great. If the differences are not methodological or procedural in origin, then they arise from inadvertent job selection and/or training. In other words, the successful Navy fighter pilots have little myopia in the dark; do the characteristics of the job select such individuals or is accommodation trained over the course of their professional experience? Steps should be taken to optimize these factors for either selection or training.

Lastly, we recommend exploring the possibility that the accommodative state in the dark may provide a useful indication of the rate of the development of refractive error or the effects of extended near work upon far vision.

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FIGURE LEGENDS

Figure 1. Distribution of accommodation in the dark of 220 college students. All measurements were taken with a laser optometer with the observers wearing their normal optical correction. (From Leibowitz and Owens, 1978).

Figure 2. Laser-Badal optometer.

Figure 3. Data of a single observer from a single test session. The abscissa is the distance in meters of the rotating drum from the Badal lens. The direction of apparent flow of the speckle pattern is indicated on the ordinate for each run. The direction of drum rotation for each run is identified to the right of the data. The arrows indicate the distance used to calculate accommodative state.

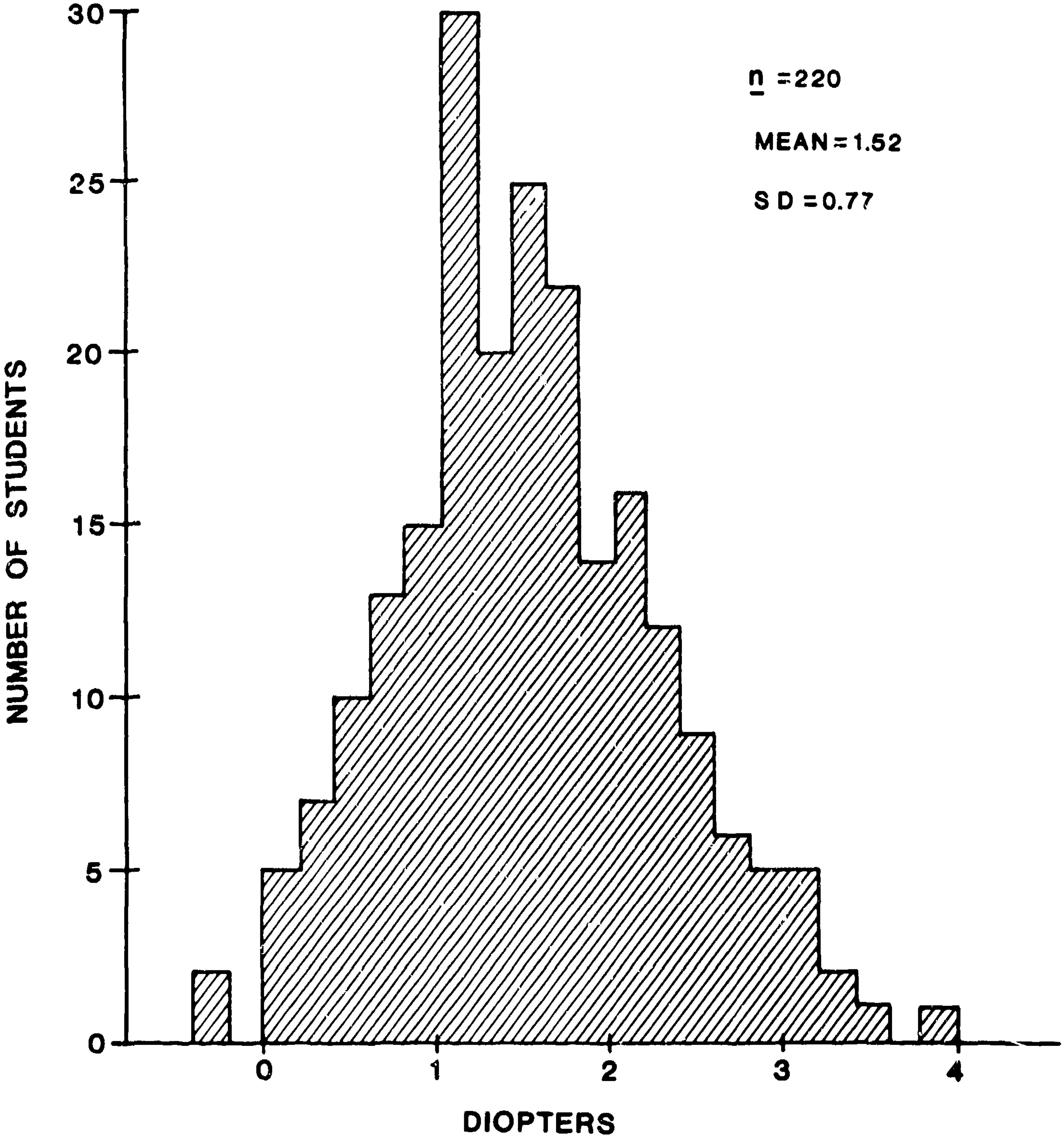
Figure 4. Data of a single observer from a single test session presented in the same format as in Figure 3.

Figure 5. Data of a single observer from a single test session presented in the same format as in Figure 3.

Figure 6. Histogram of accommodation in the dark measured in 137 aviators.

Figure 7. Cumulative frequency distributions of the frequency histograms from Figures 1 and 6.

Figure 8. The solid line is the cumulative frequency distribution of the 137 aviators which combines the two histograms of aviators in Figure 6. The broken line and open triangles is the same as shown in Figure 7 depicting the college student data.



n =220
MEAN=1.52
SD=0.77
NUMBER OF STUDENTS
DIOPTERS
0
5
10
15
20
25
30
1
2
3
4

LASER-BADAL OPTOMETER

A-MOTOR DRIVE FOR FOCUSING

B-LASER

C-ELECTRIC SHUTTER

D-MOTOR DRIVE FOR DRUM

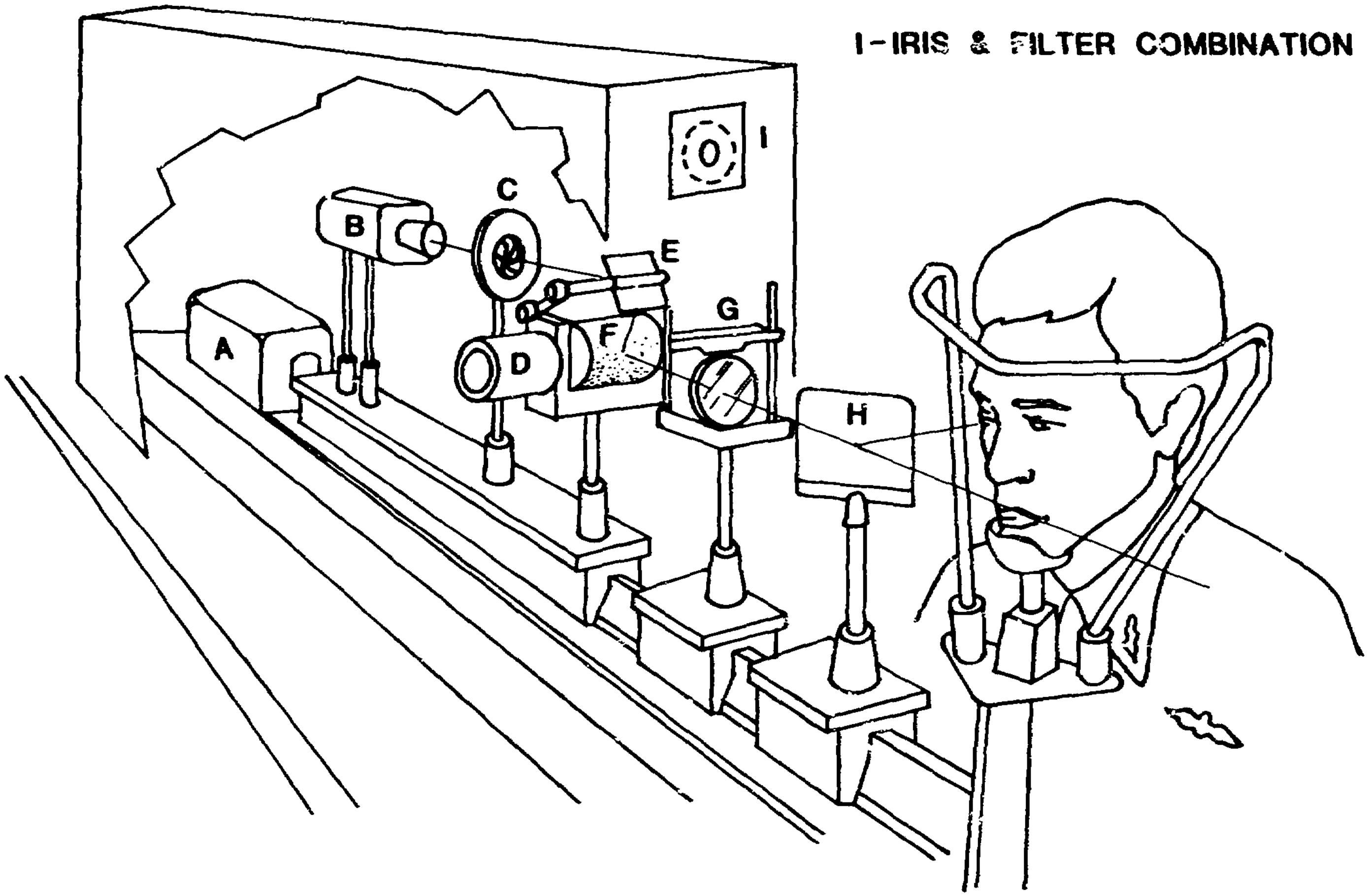
E-MIRROR

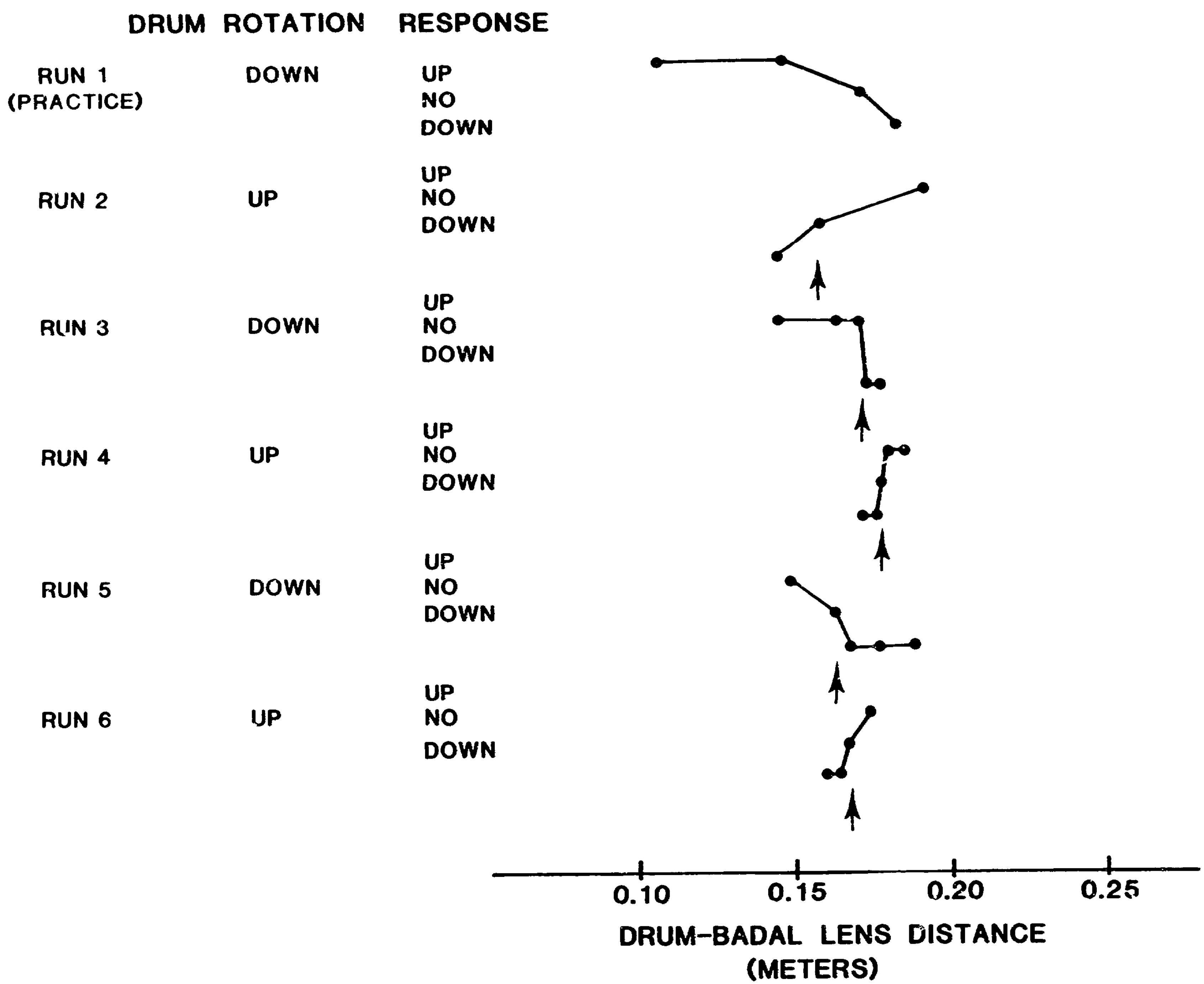
F-ROTATING CYLINDER

G-BADAL LENS

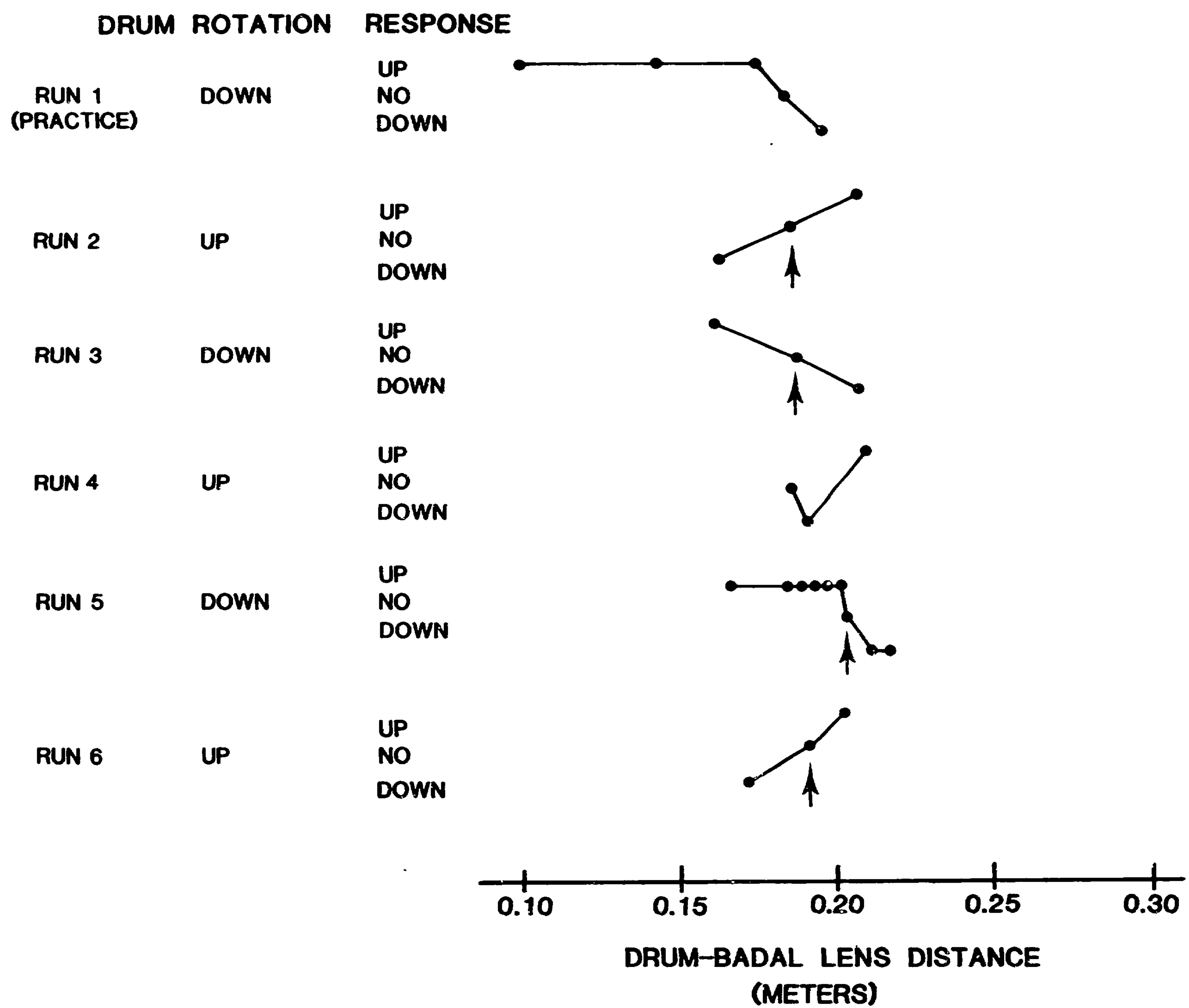
H-BEAMSPLITTER

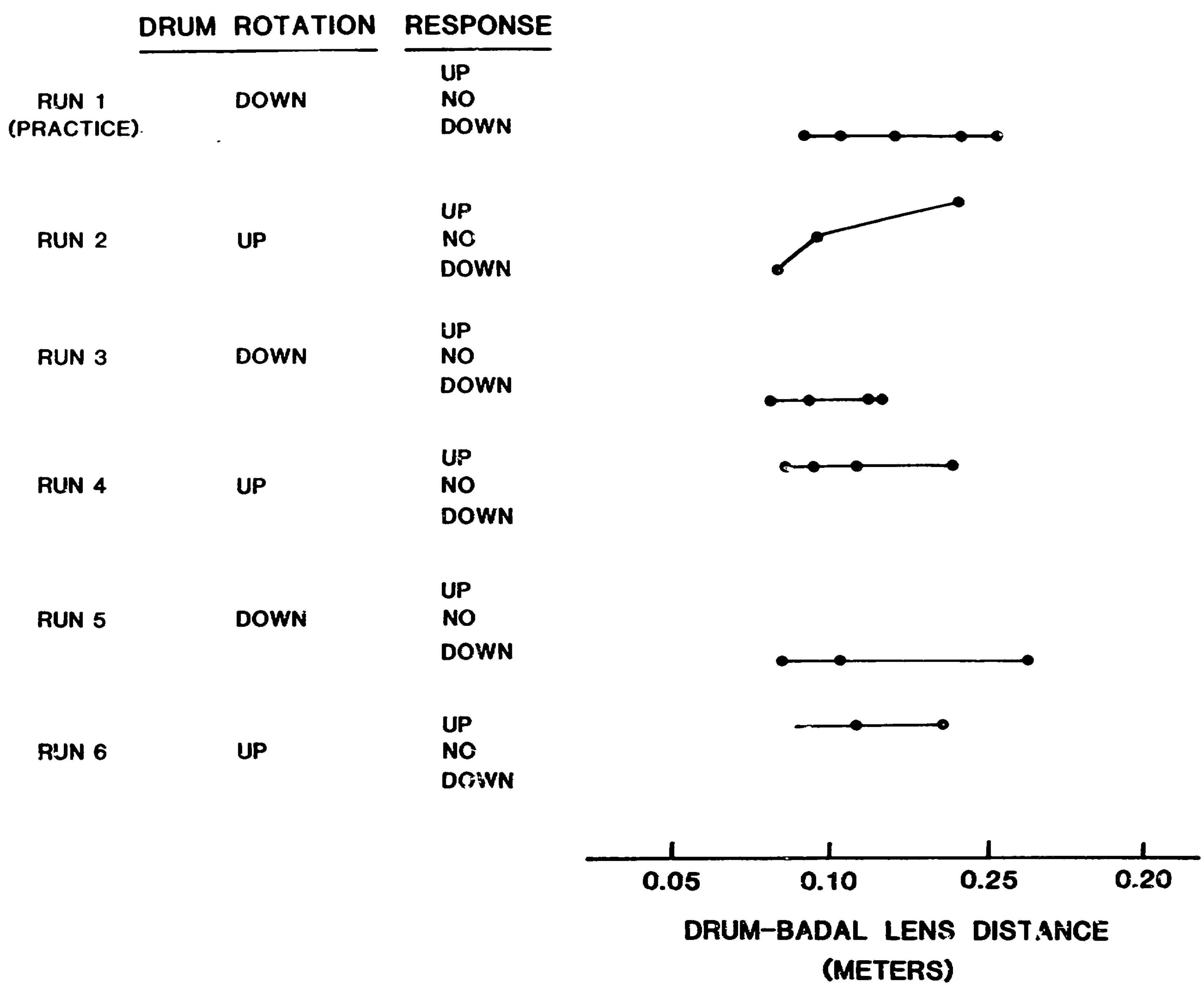
I-IRIS & FILTER COMBINATION

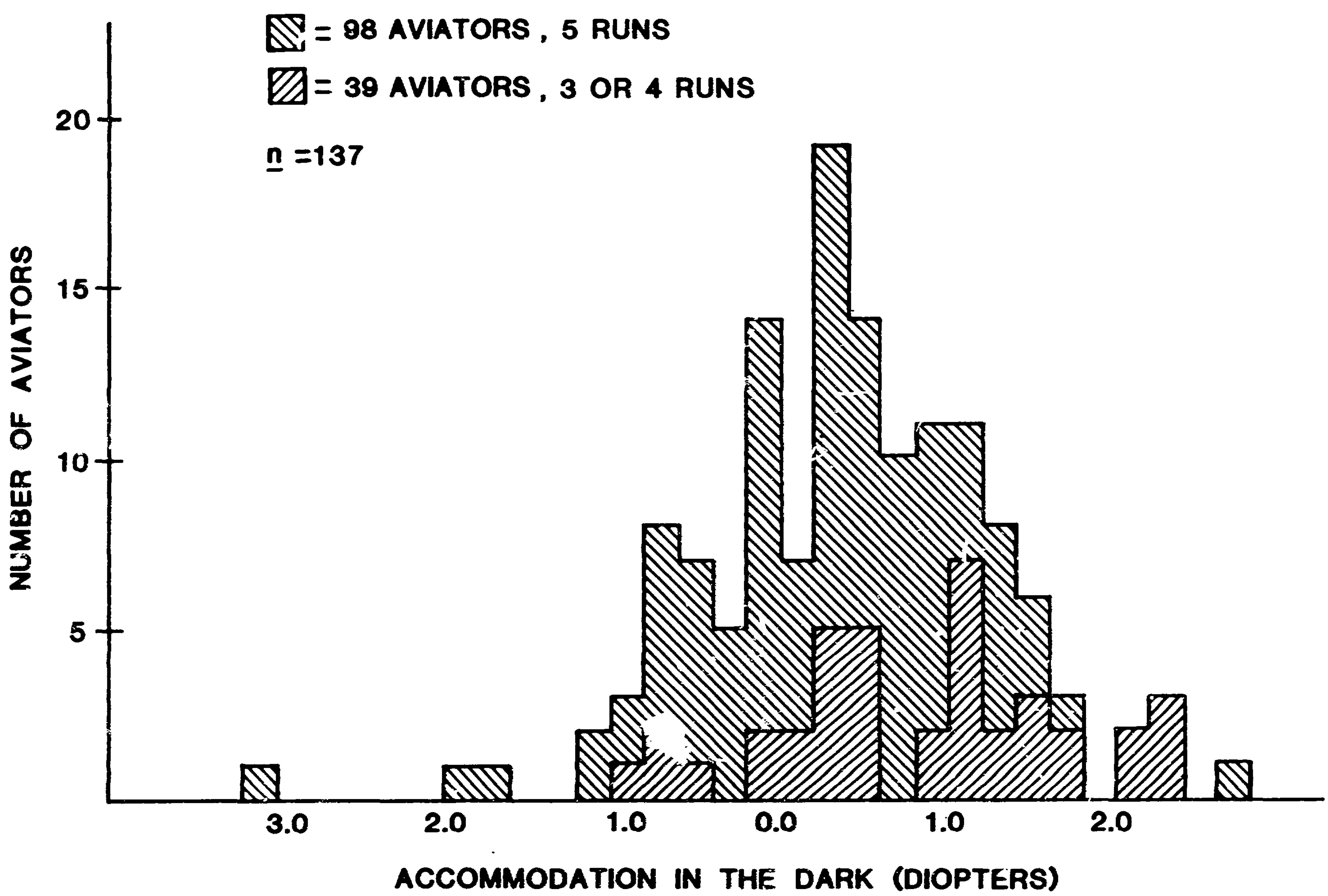


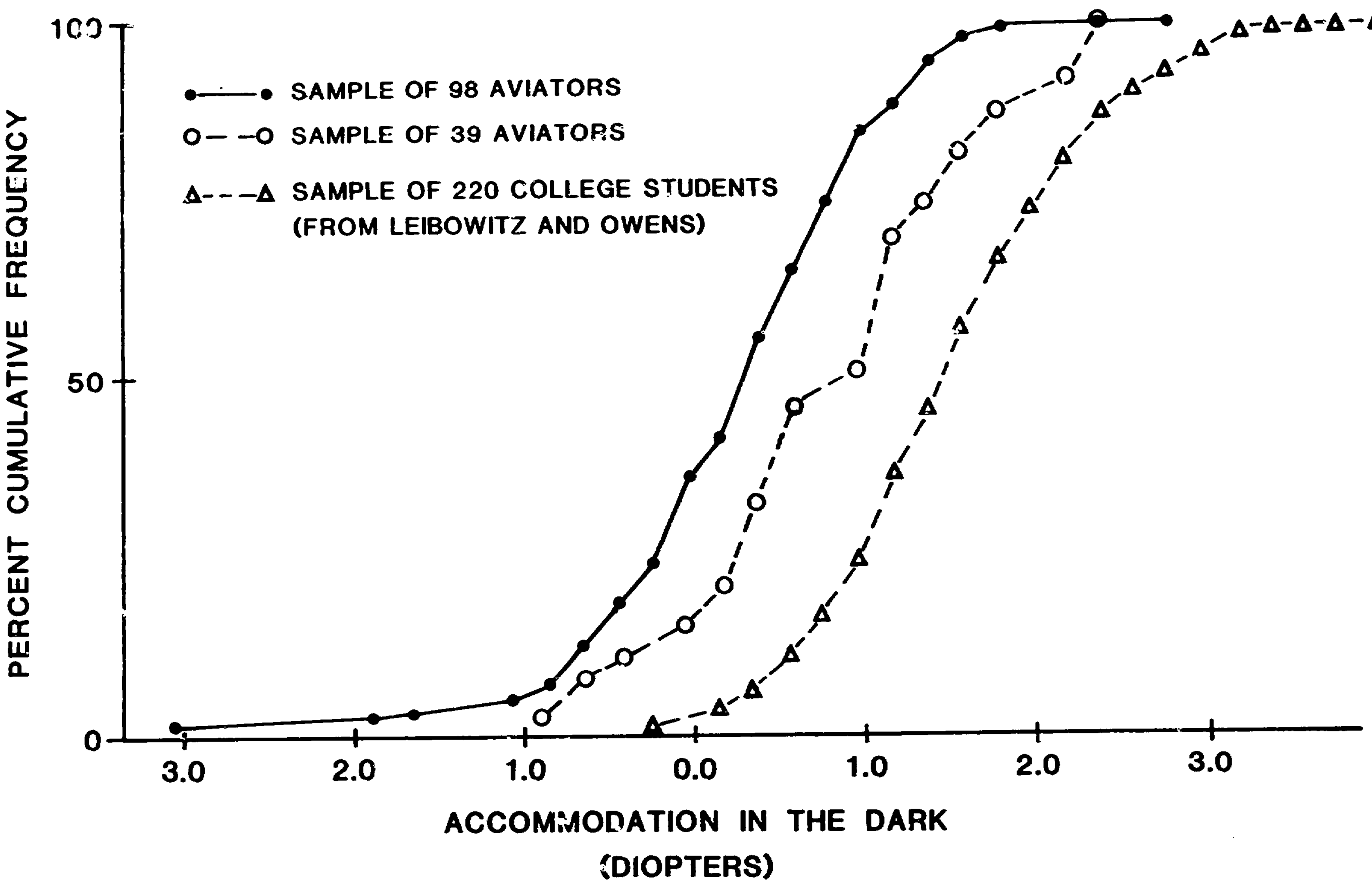


DRUM ROTATION
RESPONSE
RUN 1
(PRACTICE)
DOWN
UP
NO
DOWN
RUN 2
UP
UP
NO
DOWN
RUN 3
DOWN
UP
NO
DOWN
RUN 4
UP
UP
NO
DOWN
RUN 5
DOWN
UP
NO
DOWN
RUN 6
UP
UP
NO
DOWN
0.10
0.15
0.20
0.25
DRUM-BADAL LENS DISTANCE
(METERS)

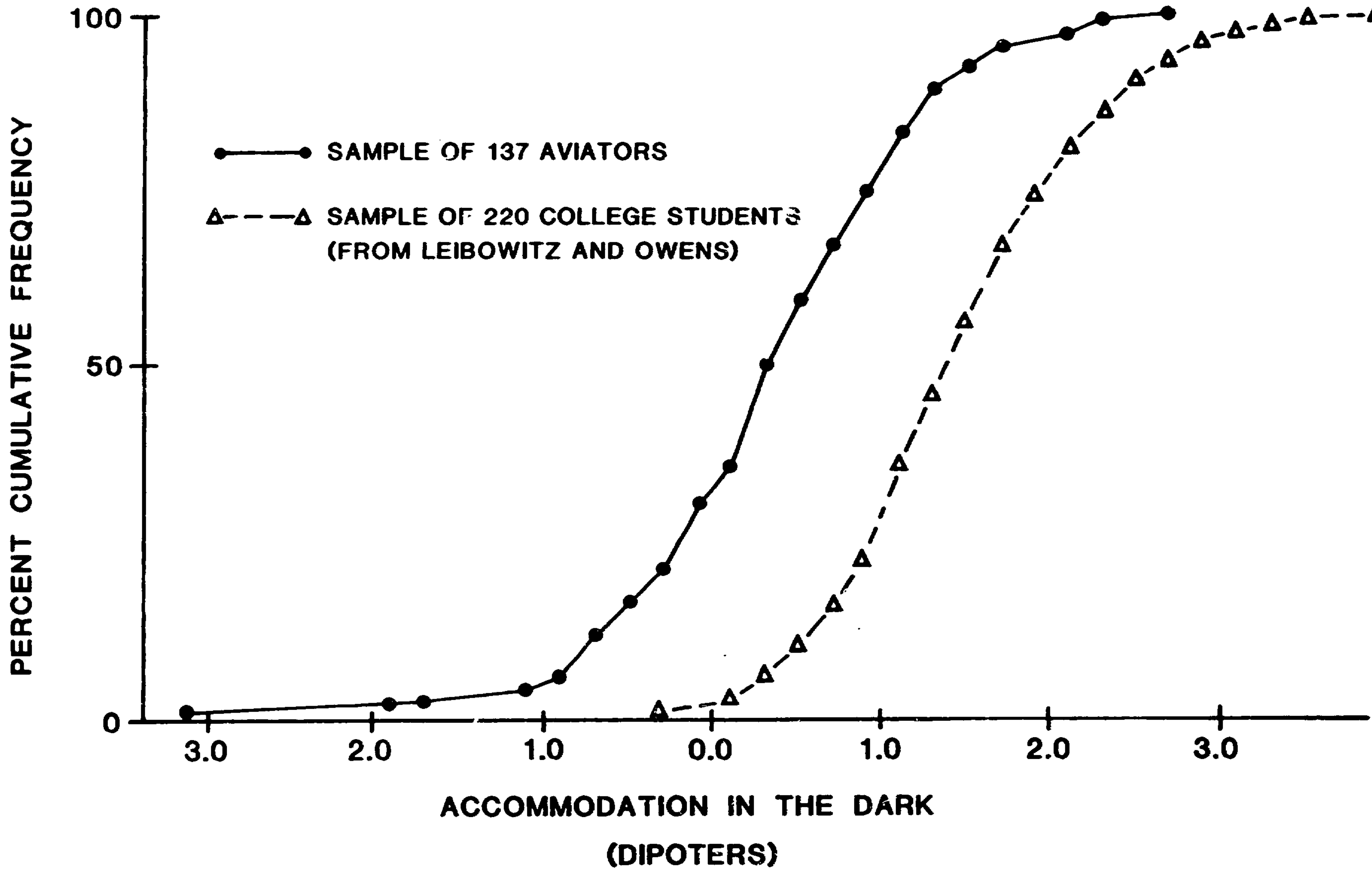

DRUM ROTATION
RESPONSE
RUN 1
(PRACTICE)
DOWN
UP
NO
DOWN
RUN 2
UP
RUN 3
DOWN
RUN 4
UP
RUN 5
DOWN
RUN 6
UP
0.10
0.15
0.20
0.25
0.30
DRUM-BADAL LENS DISTANCE
(METERS)


DRUM ROTATION
RESPONSE
RUN 1
(PRACTICE)
DOWN
UP
NO
DOWN
RUN 2
UP
UP
NO
DOWN
RUN 3
DOWN
UP
NO
DOWN
RUN 4
UP
UP
NO
DOWN
RUN 5
DOWN
UP
NO
DOWN
RUN 6
UP
UP
NO
DOWN
0.05
0.10
0.25
0.20
DRUM-BADAL LENS DISTANCE
(METERS)


= 98 AVIATORS , 5 RUNS
= 39 AVIATORS , 3 OR 4 RUNS
n =137
NUMBER OF AVIATORS
20
15
10
5
3.0
2.0
1.0
0.0
1.0
2.0
ACCOMMODATION IN THE DARK (DIOPTERS)



100
50
0
SAMPLE OF 98 AVIATORS
SAMPLE OF 39 AVIATORS
SAMPLE OF 220 COLLEGE STUDENTS
(FROM LEIBOWITZ AND OWENS)
PERCENT CUMULATIVE FREQUENCY
3.0
2.0
1.0
0.0
1.0
2.0
3.0
ACCOMMODATION IN THE DARK
(DIOPTERS)


100
50
0
PERCENT CUMULATIVE FREQUENCY
SAMPLE OF 137 AVIATORS
SAMPLE OF 220 COLLEGE STUDENTS
(FROM LEIBOWITZ AND OWENS)
3.0
2.0
1.0
0.0
1.0
2.0
3.0
ACCOMMODATION IN THE DARK
(DIPOTERS)